FORM PTO-1390 (Modified) (REV 11-98) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

3607 Rec'd PCT/PTO 23 MAR 2001

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER	U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR
L9289.01123 PCT	**New Application** 09/787795

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/JP00/04569	**July 10, 2000**	**July 28, 1999**

TITLE OF INVENTION
FREQUENCY OFFSET QUANTITY DETECTING APPARATUS

APPLICANT(S) FOR DO/EO/US
Minako IDE

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☐ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   - a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   - b. ☒ has been transmitted by the International Bureau.
   - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ A copy of the International Search Report (PCT/ISA/210).
8. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   - b. ☐ have been transmitted by the International Bureau.
   - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   - d. ☐ have not been made and will not be made.
9. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
10. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 13 to 20 below concern document(s) or information included:

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☐ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ Certificate of Mailing by Express Mail
20. ☒ Other items or information:

Claim for Priority w/PCT/IB/304
PCT/IB/308
PCT/RO/101

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U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
New Application	**PCT/JP00/04569**	**L9289.01123 PCT**

21. The following fees are submitted:.

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

		CALCULATIONS	PTO USE ONLY
☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2) paid to USPTO and International Search Report not prepared by the EPO or JPO	**$1,000.00**		
☒ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but Internation Search Report prepared by the EPO or JPO	**$860.00**		
☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO	**$710.00**		
☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4)	**$690.00**		
☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4)	**$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =		**$860.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).		**$0.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	8 - 20 =	0	x $18.00	**$0.00**	
Independent claims	4 - 3 =	1	x $80.00	**$80.00**	
Multiple Dependent Claims **(check if applicable)**.			☐	**$0.00**	
TOTAL OF ABOVE CALCULATIONS =				**$940.00**	
Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28) **(check if applicable)**.			☐	**$0.00**	
SUBTOTAL =				**$940.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). +				**$0.00**	
TOTAL NATIONAL FEE =				**$940.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable)**.			☒	**$40.00**	
TOTAL FEES ENCLOSED =				**$980.00**	
				Amount to be: refunded	$
				charged	$

☒ A check in the amount of **$980.00** to cover the above fees is enclosed.

☐ Please charge my Deposit Account No. in the amount of to cover the above fees. A duplicate copy of this sheet is enclosed.

☒ The Commissioner is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. **19-4375** A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

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DESCRIPTION

FREQUENCY OFFSET QUANTITY DETECTING APPARATUS

Technical Field

The present invention relates to a frequency offset quantity detecting apparatus, and more particularly to a frequency offset quantity detecting apparatus and a frequency offset quantity detecting method thereof for the use of a communication apparatus for digital mobile communication.

Background Art

When radio communication is performed, the radio frequency of a transmitting end and the radio frequency of a receiving end are basically made to be the same. However, actually, a gap between them of about several ppm to several tens ppm occurs owing to the accuracy of their reference clocks. To estimate the frequency gap and correct it is called frequency offset compensation (Automatic Frequency Compensation; hereinafter abbreviated as AFC).

While analog communication was the mainstream, as the AFC, there was used a method in which the receiving end swept the frequency of its clock source in an arbitrary range to select a point having a high reception level, or the like. However, in these days when radio digital communication is the mainstream, there is used a method

in which the frequency offset quantity is estimated on the basis of a digital signal obtained by the A/D conversion of a received signal demodulated to a baseband frequency band to correct the frequency gap.

Although various methods are used and examined as the method of the estimation of the frequency offset quantity, there is generally known a method in which a phase difference between a former reception data and a latter reception data is obtained to remove the difference value owing to data modulation for obtaining the frequency offset quantity.

In this case, because the initial pulling into synchronism takes time in case of the use of known signals, which are limited in number, there is proposed a method for detecting the frequency offset quantity by using unknown signals (data signals) for pursuing transmission efficiency.

Hereinafter, a conventional reception apparatus will be described by reference to FIG. 1 to FIG. 3. FIG. 1 is a block diagram showing the schematic configuration of a conventional reception apparatus; FIG. 2 is a block diagram showing the schematic configuration of the AFC section of the conventional reception apparatus; and FIG. 3 is graphs showing an example of an I-Q plane for illustrating frequency offsets. Incidentally, here, the reception apparatus for the use of mobile communication in the code division multiple access (CDMA) system is

examined.

In FIG. 1, an antenna 1 receives a radio signal, and a radio modulation demodulation section 2 converts the received signal from a high frequency signal to a baseband signal and outputs it to a reception procession section 3. The reception procession section 3 is composed of an A/D conversion section 4, a correlation section 5, an AFC section 6, a decoding section 7, and a error correction section 8. The A/D conversion section 4 performs the A/D conversion processing of an input received signal, and the correlation section 5 composed of, for example, a matched filer detects a demodulated signal.

The AFC section 6 detects a frequency offset quantity on the basis of the demodulated signal output from the correlation section 5, and outputs the detected frequency offset quantity to the decoding section 7 and a clock source 10. The details will be described later.

The decoding section 7 performs the phase compensation processing of the input demodulated signal on the basis of the frequency offset quantity being an output of the AFC section 6, and then performs the soft decision processing of the processed signal. The error correction section 8 performs the codec processing such as the de-interleave processing and the error correction processing of the decided signal, and outputs the processed signal to a baseband signal processing section 9. The baseband signal processing section 9 obtains the

received data from the received signal after the reception processing thereof was performed by the reception processing section 3, and also obtains and transmission data to output them to a transmission processing section 11.

The clock source 10 keeps a reference clock frequency, and corrects the reference clock frequency on the basis of the frequency offset quantity that is the output of the AFC section 6, and further outputs the reference clock frequency to the radio modulation demodulation section 2, the A/D conversion section 3 and the baseband signal processing section 9. The transmission processing section 11 performs the transmission processing of a transmission baseband signal to output it to the radio modulation demodulation section 2.

Next, the configuration of the AFC section 6 and the frequency offset detection operation thereof will be described by reference to FIG. 2 and FIG. 3.

When the frequency offset is not detected by the use of known signals but is detected by the use of unknown signals (data signals), a received demodulated signal Dm is situated in any one of the first quadrant to the fourth quadrant but can not be specified. Then, if it is supposed that the noise level is sufficiently low, the demodulated signal is situated at one point in each quadrant as shown in FIG. 3A in the case where a frequency offset does not exist, but the position of the demodulated signal shifts

as the passage of time as shown in FIG. 3B in the case where the frequency offset θf exists.

Because the offset quantity θf between the received symbol that delayed by one symbol and the present received symbol is always constant, the offset quantity θf can be obtained by the operation of the difference between the received symbol that delayed by one symbol and the present received symbol.

Accordingly, a delay unit 21 delays the input received demodulated signal Dm by one symbol, and a subtracter 22 subtracts the output of the delay unit 21 from the present symbol, and further a phase detector 23 converts the subtraction result ΔDm of the subtracter 22 to a phase angle to detect a phase shift θm.

However, the phase shift θm is not equivalent to the frequency offset θf and the phase shift θm also includes a phase offset θd owing to the data modulation ($\theta m = \theta d + \theta f$). Consequently, it is necessary to remove the phase offset θd.

Now, if the modulation system is supposed to be the quadrature phase shift keying (QPSK), the phase offset θd is 0°, 90°, 180° and 270°. Because these values become multiples of 360° by the multiplication by four, the frequency offset θf can be obtained by the removal of θd from θm by the following computation formula.

$$((4 \times \theta m) \bmod (360°)) / 4$$

$$= ((4 \times (\theta d + \theta f)) \bmod (360°)) / 4$$

$$=((4\theta d + 4\theta f) \bmod (360°)) / 4$$

$$=4\theta f/4$$

$$=\theta f$$

Accordingly, the frequency offset θf is obtained by the following: the phase difference θm is multiplied by four by a multiplier 24, and the remainder when the output of the multiplier 24 is divided by 360° is calculated by a modulo (mod) arithmetic unit 25, and 4 θf is multiplied by 1/4 by a multiplier 26. Then, last, an averaging section 27 averages the frequency offset quantity θf in an arbitrary interval to perform the estimation and the correction of the frequency offset quantity.

As described above, because the conventional frequency offset detecting method uses not only the limited known signals but also data signals, the shortening of the initial pulling time of the AFC is possible.

However, the conventional frequency offset detecting method has a problem that the accuracy of estimation can be deteriorated because the method uses the received signal at a step before the performance of the error correction processing.

Because the bit error ratio (BER) after error correction supposed in the future cellular system using CDMA or the like is about 10-3, the BER of a signal before the error correction is equal to or more than 10-1 when

it is reckoned back. When the frequency offset quantity is estimated by the use of a signal having such a BER, the deterioration of the estimation accuracy becomes large and the initial pulling can be difficult.

Disclosure of Invention

An object of the present invention is to provide a reception apparatus and a frequency offset quantity estimation method thereof for the improvement of frequency offset quantity estimation accuracy as well as the shortening of the initial pulling time.

A subject matter of the present invention is to aim the improvement of frequency offset quantity estimation accuracy by the use of a known signal and to aim the shortening of initial pulling time by picking up the large number of phase difference samples from the limited symbol information by the use of one-symbol phase difference information and two-symbol phase difference information together with the known signal.

Brief Description of Drawings

FIG. 1 is a block diagram showing the schematic configuration of a conventional reception apparatus;

FIG. 2 is a block diagram showing the schematic configuration of the AFC section of the conventional reception apparatus;

FIG. 3A is a graph showing an example of I-Q plane

for illustrating a frequency offset;

FIG. 3B is a graph showing the example of the I-Q plane for illustrating a frequency offset;

FIG. 4 is a block diagram showing the schematic configuration of the AFC section of a reception apparatus according to embodiment 1 of the present invention;

FIG. 5 is a block diagram showing the schematic configuration of the AFC section of a reception apparatus according to embodiment 2 of the present invention;

FIG. 6 is a block diagram showing the schematic configuration of the AFC section of a reception apparatus according to embodiment 3 of the present invention; and

FIG. 7 is a graph for illustrating the calculation method for making the angular component of a complex signal the half thereof.

Best Mode for Carrying Out the Invention

Hereinafter, embodiments of the present invention will be described in detail by reference to the drawings.

(EMBODIMENT 1)

The reception apparatus according to the embodiment 1 detects a frequency offset quantity by the use of the one-symbol phase difference information and the two-symbol phase difference information of a known symbol.

Hereinafter, the reception apparatus according to the present embodiment will be described by reference to FIG. 4. FIG. 4 is a block diagram showing the schematic

configuration of the AFC section of the reception apparatus according to the embodiment 1 of the present invention.

In FIG. 4, a delay unit 101 delays a received known symbol Dm input into the AFC section by one symbol and outputs one-symbol delayed received known symbol Dm-1, and a subtracter 102 performs the subtraction processing of the one-symbol delayed received known symbol Dm-1 from the received symbol Dm to output the subtraction result ΔDm1.

A delay unit 103 delays the input one-symbol delayed received known symbol Dm-1 by one symbol to output a two-symbol delayed received known symbol Dm-2, and a subtracter 104 performs the subtraction processing of the two-symbol delayed received known symbol Dm-2 from the received symbol Dm to output the subtraction result ΔDm2.

A phase detecting section 105 converts the subtraction result ΔDm1 to a phase angle and detects a phase shift θm1, and a phase detecting section 106 converts the subtraction result ΔDm2 to a phase angle and detects a phase shift θm2.

Here, the phase shifts θm1, θm2 are not equivalent to the frequency offset θf, but the phase shifts θm1, θm2 severally include a phase offset owing to the data modulation of the reception signal, too. But, if the modulation system is known, the phase offset owing to the

data modulation of a known signal is known. Accordingly, a memory 107 keeps phase offsets $\phi m1$, $\phi m2$ owing to the data modulation of known symbols beforehand.

A subtracter 108 performs the subtraction processing of the phase offset $\phi m1$ from the phase shift $\theta m1$, and a subtracter 109 performs the subtraction processing of the phase offset $\phi m2$ from the phase shift $\theta m2$. A multiplier 110 multiplies the output of the subtracter 109, which is the frequency offset quantity for two symbols, by 1/2 to adjust the output to be for one symbol.

An averaging section 111 averages the output of the subtracter 108 and the output of the multiplier 110 for an arbitrary interval, and outputs the averaged value as an estimated frequency offset quantity.

Next, the operation of the apparatus having the aforesaid configuration will be described.

The received symbol Dm is delayed by one symbol by the delay unit 101, and the subtraction processing of the one-symbol delayed received known symbol Dm-1 from the received symbol Dm is performed by the subtracter 102.

The one-symbol delayed received known symbol Dm-1 is delayed by one symbol by the delay unit 103, and the subtraction processing of the two-symbol delayed received known symbol Dm-2 from the received symbol Dm is performed by the subtracter 104.

The calculated subtraction results $\Delta Dm1$, $\Delta Dm2$ are converted to the phase shifts $\theta m1$, $\theta m2$ by the phase

detection sections 105, 106, respectively, and the subtraction processing of the phase offsets ϕm1, ϕm2 from the phase shifts θm1, θm2 is performed by the subtracters 108, 109, respectively.

The averaging processing of the output of the subtracter 108 and the output of the subtracter 109 to which 1/2 is multiplied by the multiplier 110 is performed by the averaging section 111, and the averaged output is output as an estimated frequency offset quantity.

As described above, according to the present embodiment, the number of samples is increased not only by the use of a known signal together with the one-symbol phase difference information but also by the use of the two-symbol phase difference information. Consequently, it becomes possible to realize the improvement of the estimation accuracy of the frequency offset quantity and the shortening of the initial pulling time of the frequency offset compensation simultaneously.

(EMBODIMENT 2)

The reception apparatus according to the present embodiment has a configuration similar to that of the embodiment 1, but the present embodiment beforehand converts the received known symbol to a phase rotation quantity being a complex signal.

Hereinafter, the reception apparatus according to the present embodiment will be described by reference to FIG. 5. FIG. 5 is a block diagram showing the schematic

configuration of the AFC section of a reception apparatus according to the embodiment 2 of the present invention. Incidentally, the constituent elements similar to those of the embodiment 1 are designated by the same reference marks as those of the embodiment 1, and their detailed descriptions are omitted.

A phase rotation detecting section 201 detects the phase rotation quantity Rm (complex signal) of a received known symbol by the use of a known signal stored in a memory 202.

After that, the processing similar to that of embodiment 1 is performed by the use of the phase rotation quantity Rm in place of the received known symbol Dm for detecting the frequency offset θf. That is, the phase rotation quantity Rm is delayed by one symbol by the delay unit 101, and the subtraction processing of the one-symbol delayed phase rotation quantity Rm-1 from the phase rotation quantity Rm is performed by the subtracter 102. The one-symbol delayed phase rotation quantity Rm-1 is delayed by one symbol by the delay unit 103, and the subtraction processing of the two-symbol delayed phase rotation quantity Rm-2 from the phase rotation quantity Rm is performed by the subtracter 104. The calculated subtraction results ΔRm1, ΔRm2 are converted to the phase shifts θm1, θm2 by the phase detecting sections 105, 106, respectively. The averaging processing of the output of the phase detecting section 105 and the output of the phase

detecting section 106 to which 1/2 is multiplied by the multiplier 110 is performed by the averaging section, and the processed output is output as an estimated frequency offset quantity.

In the embodiment, because the processing is performed after the previous conversion of the received symbol to the phase rotation quantity being a complex signal before the delaying of the received symbol, the phase offset removing processing by the subtracters 108, 109 in FIG. 4 becomes unnecessary.

As described above, according to the present embodiment, the frequency offset detecting processing is performed after the previous conversion of the received known symbol to the phase rotation quantity being a complex signal, and thereby the process of the subtraction of the phase offset owing to data modulation from the detected phase shift can be omitted. Consequently, it becomes possible to realize the improvement of the estimation accuracy of the frequency offset quantity and the shortening of the initial pulling time of the frequency offset compensation simultaneously in a simpler configuration.

(EMBODIMENT 3)

The reception apparatus according to the present embodiment has a configuration similar to that of the embodiment 2, but converts the phase rotation quantity to a phase shift angle after the averaging processing.

Hereinafter, the reception apparatus according to the present embodiment will be described by reference to FIG. 6 and FIG. 7. FIG. 6 is a block diagram showing the schematic configuration of the AFC section of a reception apparatus according to the embodiment 3 of the present invention, and FIG. 7 is a graph for illustrating a calculation method for making the angular component of a complex signal a half thereof. Incidentally, the constituent components similar to those of the embodiment 2 are designated by the same reference marks as those of the embodiment 2, and their detailed descriptions are omitted.

Because ΔRm2 being the output of the subtracter 104 in FIG. 6 is a phase rotation quantity for two symbols, it is necessary that the angular component of the ΔRm2 being a vector quantity is converted to a half thereof. Hereinafter, the conversion principle will be explained by the use of FIG. 7.

In FIG. 7, it is supposed that the angular component of an arbitrary complex signal V is made to be a half thereof without the use of angular information. When a rhombus two sides of which are I axis and the original complex signal V on the I-Q plane is considered, the diagonal line vector from the origin to the residual one vertex is a vector that divides the angular component of the complex signal V into two equal parts. Accordingly, by the addition of a complex signal ($|V|$, 0) that is

parallel to the positive direction of the I axis and is sized as large as the complex signals V to the original complex signal V, a complex signal V′ the angular component of which is a half of that of the original complex signal V can be obtained.

Accordingly, in FIG. 6, a vector generating section 301 generates a complex signal ($|\Delta Rm2|$, 0) that is parallel to the positive direction of the I axis and has the same largeness as that of the complex signal $\Delta Rm2$, and an adder 302 performs the addition processing of the complex signal ($|\Delta Rm2|$, 0) and the complex signal $\Delta Rm2$ to output a complex signal $\Delta Rm2'$ having an angular component of a half of that of the complex signal $\Delta Rm2$ to the averaging section 111. A phase detecting section 303 detects a phase angle in the complex signal the averaging processing of which was performed to output the detected phase angle as an estimated frequency offset quantity.

As described above, according to the present embodiment, the averaging processing of two kinds of phase difference information in a state of complex signals is performed, and consequently the processes of detecting a phase angle from a complex signal can be converged to one time of performance after averaging processing. Thereby, it becomes possible to realize the improvement of the estimation accuracy of the frequency offset quantity and the shortening of the initial pulling time

of the frequency offset compensation simultaneously in a simpler configuration.

Incidentally, although the communication system of the CDMA system is cited as an example in the embodiments 1-3, the present invention may be applied to any reception apparatus using the radio AFC and its communication system is indifferent.

Moreover, as the averaging method in the averaging section, there can be used arbitrary methods according to the system such as the method of moving average, and a weighted averaging method using a forgetting coefficient.

A frequency offset quantity detecting apparatus according to the present invention has a configuration comprising: a first detecting section for subtracting a previously held phase offset quantity owing to data modulation from a phase shift angle detected from one-symbol phase difference information of a received known symbol; a second detecting section for subtracting the previously held phase offset quantity owing to data modulation from a phase shift angle detected from two-symbol phase difference information of the received known symbol, and for multiplying the subtracted two-symbol phase difference information by 1/2; and an averaging section for averaging an output value of the first detecting section and an output value of the second detecting section for an arbitrary interval, and for

outputting an averaged output value.

According to the configuration, because the number of samples is increased by the use of not only a known signal together with the one-symbol phase difference information but also two-symbol phase difference information, it becomes possible to realize the improvement of the estimation accuracy of the frequency offset quantity and the shortening of the initial pulling time of the frequency offset compensation simultaneously.

The frequency offset quantity detecting apparatus according to the present invention has a configuration comprising a converting section for converting the received known symbol to a complex signal at a previous step of the first detecting section and the second detecting section.

According to the configuration, because a step of subtracting a phase offset owing to data modulation from the detected phase shift can be omitted by performing the detection processing of the frequency offset quantity after converting the received known symbol to a phase rotation quantity being a complex signal beforehand, it becomes possible to realize the improvement of the estimation accuracy of the frequency offset quantity and the shortening of the initial pulling time of the frequency offset compensation simultaneously in a simpler configuration.

The frequency offset quantity detecting apparatus

according to the present invention has a configuration wherein the second detecting section includes an operation section for multiplying a phase angle of the complex signal by 1/2 by vector operation.

According to the configuration, because the step of detecting phase angles from the complex signals can be converged to one time of performance after averaging processing by performing the averaging processing of two kinds of phase difference information in a state of complex signals, it becomes possible to realize the improvement of the estimation accuracy of the frequency offset quantity and the shortening of the initial pulling time of the frequency offset compensation simultaneously in a simpler configuration.

A frequency offset quantity detecting method according to the present invention comprising: a first detecting step of subtracting a previously held phase offset quantity owing to data modulation from a phase shift angle detected from one-symbol phase difference information of a received known symbol; a second detecting step of subtracting the previously held phase offset quantity owing to data modulation from a phase shift angle detected from two-symbol phase difference information of the received known symbol, and of multiplying the subtracted two-symbol phase difference information by 1/2; and an averaging step of averaging an output value at the first detecting step and an output value at the

second detecting step for an arbitrary interval, and of outputting an averaged output value.

According to the configuration, because the number of samples is increased by the use of not only a known signal together with the one-symbol phase difference information but also two-symbol phase difference information, it becomes possible to realize the improvement of the estimation accuracy of the frequency offset quantity and the shortening of the initial pulling time of the frequency offset compensation simultaneously.

The frequency offset quantity detecting method according to the present invention converts the received known symbol to a complex signal at a previous step of the first detecting step and the second detecting step.

According to the configuration, because a step of subtracting a phase offset owing to data modulation from the detected phase shift can be omitted by performing the detection processing of the frequency offset quantity after converting the received known symbol to a phase rotation quantity being a complex signal beforehand, it becomes possible to realize the improvement of the estimation accuracy of the frequency offset quantity and the shortening of the initial pulling time of the frequency offset compensation simultaneously in a simpler configuration.

The frequency offset quantity detecting method according to the present invention multiplies a phase

angle of the complex signal by 1/2 by vector operation in the second detecting step.

According to the method, because the step of detecting phase angles from the complex signals can be converged to one time of performance after averaging processing by performing the averaging processing of two kinds of phase difference information in a state of complex signals, it becomes possible to realize the improvement of the estimation accuracy of the frequency offset quantity and the shortening of the initial pulling time of the frequency offset compensation simultaneously in a simpler configuration.

As described above, according to the present invention, because a large number of phase difference samples are picked up from the limited symbol information by the use of a known signal and by the use of one-symbol phase difference information and two-symbol phase difference information together with the known signal, it becomes possible to realize the improvement of the estimation accuracy of the frequency offset quantity and the shortening of the initial pulling time of the frequency offset compensation simultaneously.

This application is based on the Japanese Patent Application No. HEI 11-213955 filed on July 28, 1999, entire content of which is expressly incorporated by reference herein.

Industrial Applicability

The present invention can be applied to a communication terminal apparatus and a base station apparatus in a digital radio communications system. Thereby, because a large number of phase difference samples are picked up from the limited symbol information by the use of a known signal together with the one-symbol phase difference information and the two-symbol phase difference information, it becomes possible to realize the improvement of the estimation accuracy of the frequency offset quantity and the shortening of the initial pulling time of the frequency offset compensation simultaneously.

CLAIMS

1. A frequency offset quantity detecting apparatus comprising:

first detecting means for subtracting a previously held phase offset quantity owing to data modulation from a phase shift angle detected from one-symbol phase difference information of a received known symbol;

second detecting means for subtracting the previously held phase offset quantity owing to data modulation from a phase shift angle detected from two-symbol phase difference information of the received known symbol, and for multiplying the subtracted two-symbol phase difference information by 1/2; and

averaging means for averaging an output value of said first detecting means and an output value of said second detecting means for an arbitrary interval, and for outputting an averaged output value.

2. The frequency offset quantity detecting apparatus according to claim 1, said apparatus further comprising converting means for converting the received known symbol to a complex signal at a previous step of said first detecting means and said second detecting means.

3. The frequency offset quantity detecting apparatus according to claim 2, wherein said second detecting means includes an operation section for multiplying a phase angle of the complex signal by 1/2 by vector operation.

4. A communication terminal apparatus equipped with

a frequency offset quantity detecting apparatus, said frequency offset quantity detecting apparatus comprising:

first detecting means for subtracting a previously held phase offset quantity owing to data modulation from a phase shift angle detected from one-symbol phase difference information of a received known symbol;

second detecting means for subtracting the previously held phase offset quantity owing to data modulation from a phase shift angle detected from two-symbol phase difference information of the received known symbol, and for multiplying the subtracted two-symbol phase difference information by 1/2; and

averaging means for averaging an output value of said first detecting means and an output value of said second detecting means for an arbitrary interval, and for outputting an averaged output value.

5. A base station apparatus including a frequency offset quantity detecting apparatus, said frequency offset quantity detecting apparatus comprising:

first detecting means for subtracting a previously held phase offset quantity owing to data modulation from a phase shift angle detected from one-symbol phase difference information of a received known symbol;

second detecting means for subtracting the previously held phase offset quantity owing to data modulation from a phase shift angle detected from

two-symbol phase difference information of the received known symbol, and for multiplying the subtracted two-symbol phase difference information by 1/2; and

averaging means for averaging an output value of said first detecting means and an output value of said second detecting means for an arbitrary interval, and for outputting an averaged output value.

6. A frequency offset quantity detecting method comprising:

a first detecting step of subtracting a previously held phase offset quantity owing to data modulation from a phase shift angle detected from one-symbol phase difference information of a received known symbol;

a second detecting step of subtracting the previously held phase offset quantity owing to data modulation from a phase shift angle detected from two-symbol phase difference information of the received known symbol, and of multiplying the subtracted two-symbol phase difference information by 1/2; and

an averaging step of averaging an output value at said first detecting step and an output value at said second detecting step for an arbitrary interval, and of outputting an averaged output value.

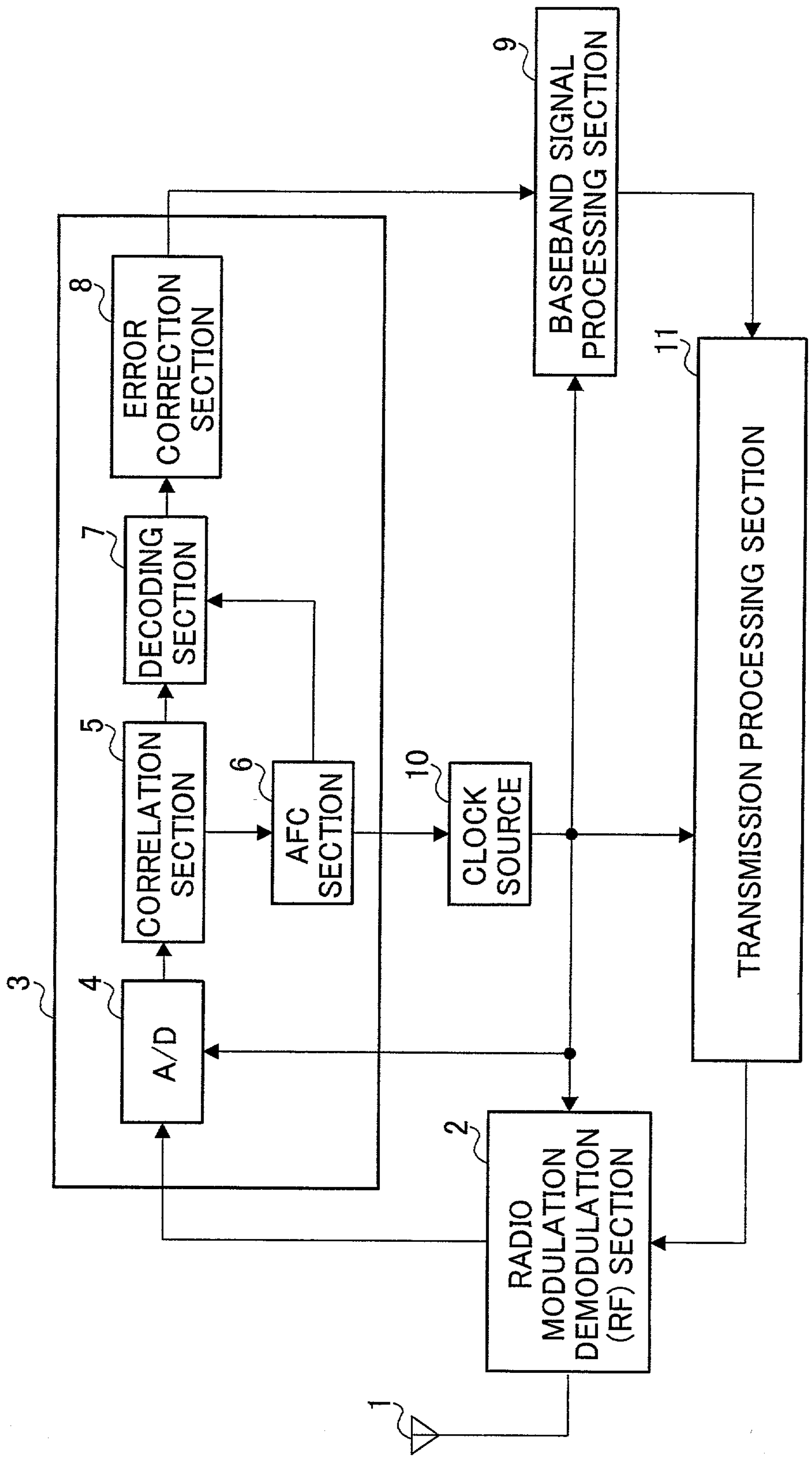
7. The frequency offset quantity detecting method according to claim 6, said method further comprising a converting step of converting the received known symbol to a complex signal at a previous step of said first

detecting step and said second detecting step.

8. The frequency offset quantity detecting method according to claim 7, wherein in said second detecting step, a phase angle of the complex signal is multiplied by 1/2 by vector operation.

ABSTRACT

A delay unit 101 delays a received known symbol input into an AFC section by one symbol; a subtracter 102 subtracts the one-symbol delayed received known symbol from the received symbol; a delay unit 103 delays the input one-symbol delayed received known symbol by one symbol; a subtracter 104 subtracts two-symbol delayed received known symbol from the received symbol; phase detecting sections 105, 106 severally convert the subtraction results to phase angles to detect phase shifts; subtracters 108, 109 severally perform the subtraction processing of phase offsets from the phase shifts, a multiplier 110 multiplies the output of the subtracter 109 by 1/2; and an averaging section 111 averages the output of the subtracter 108 and the output of the multiplier 110 for an arbitrary interval.



9
BASEBAND SIGNAL PROCESSING SECTION
3
4
A/D
5
CORRELATION SECTION
6
AFC SECTION
7
DECODING SECTION
8
ERROR CORRECTION SECTION
10
CLOCK SOURCE
11
TRANSMISSION PROCESSING SECTION
2
RADIO MODULATION DEMODULATION (RF) SECTION
1

FIG.1

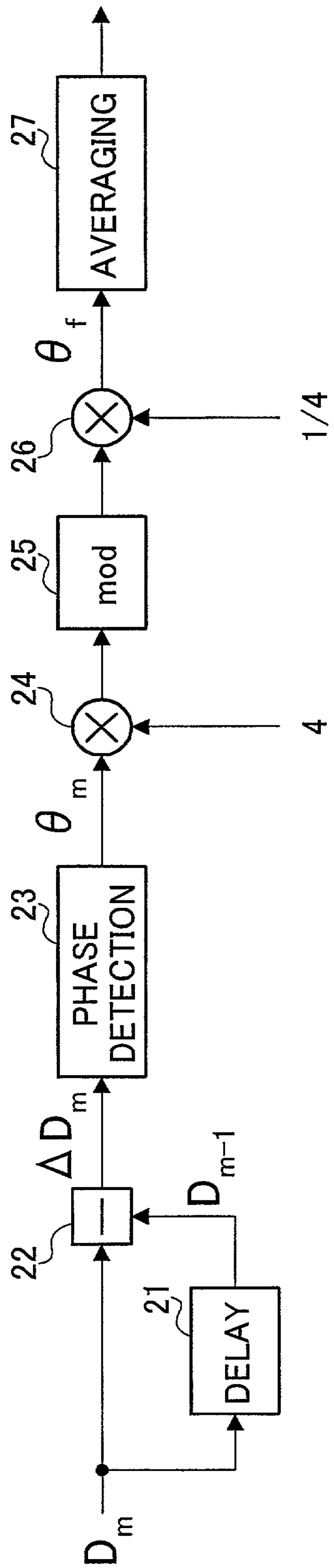

D
m
DELAY
21
22
—
D_{m-1}
ΔD_m
23
PHASE DETECTION
θ_m
24
4
25
mod
26
1/4
θ_f
27
AVERAGING

FIG.2

09/787795

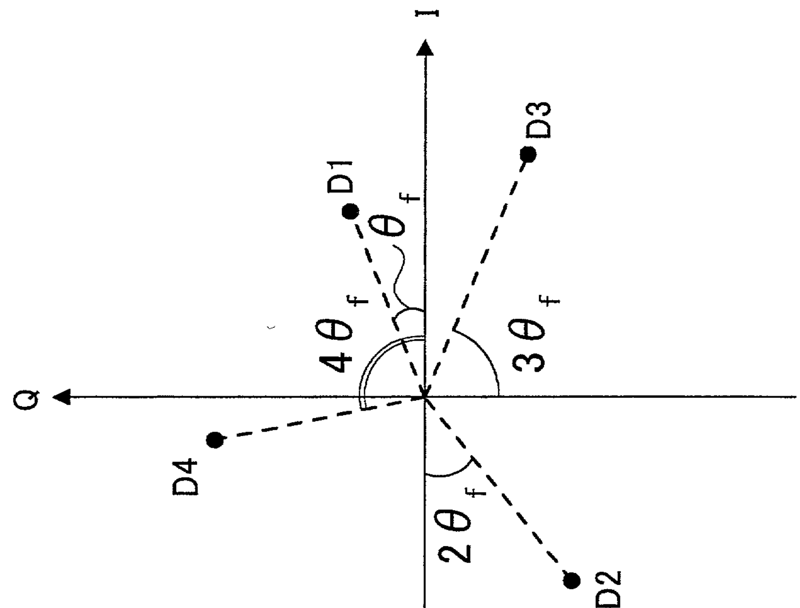


FIG.3B

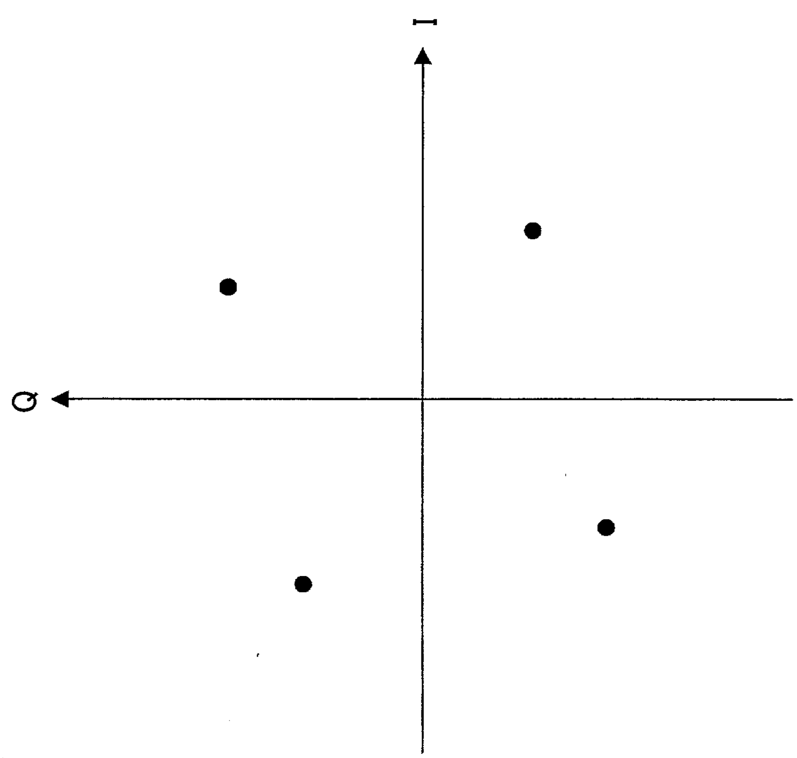
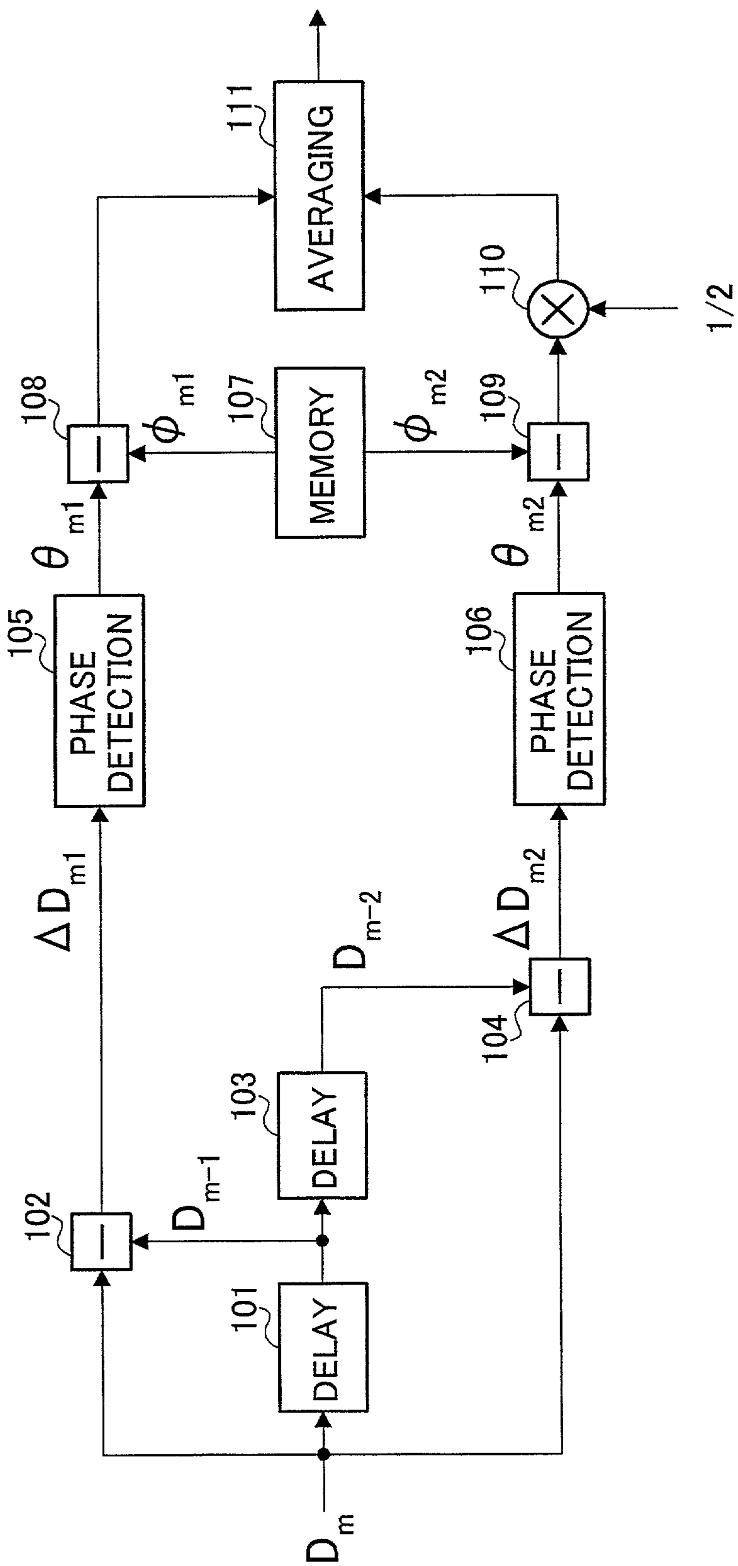
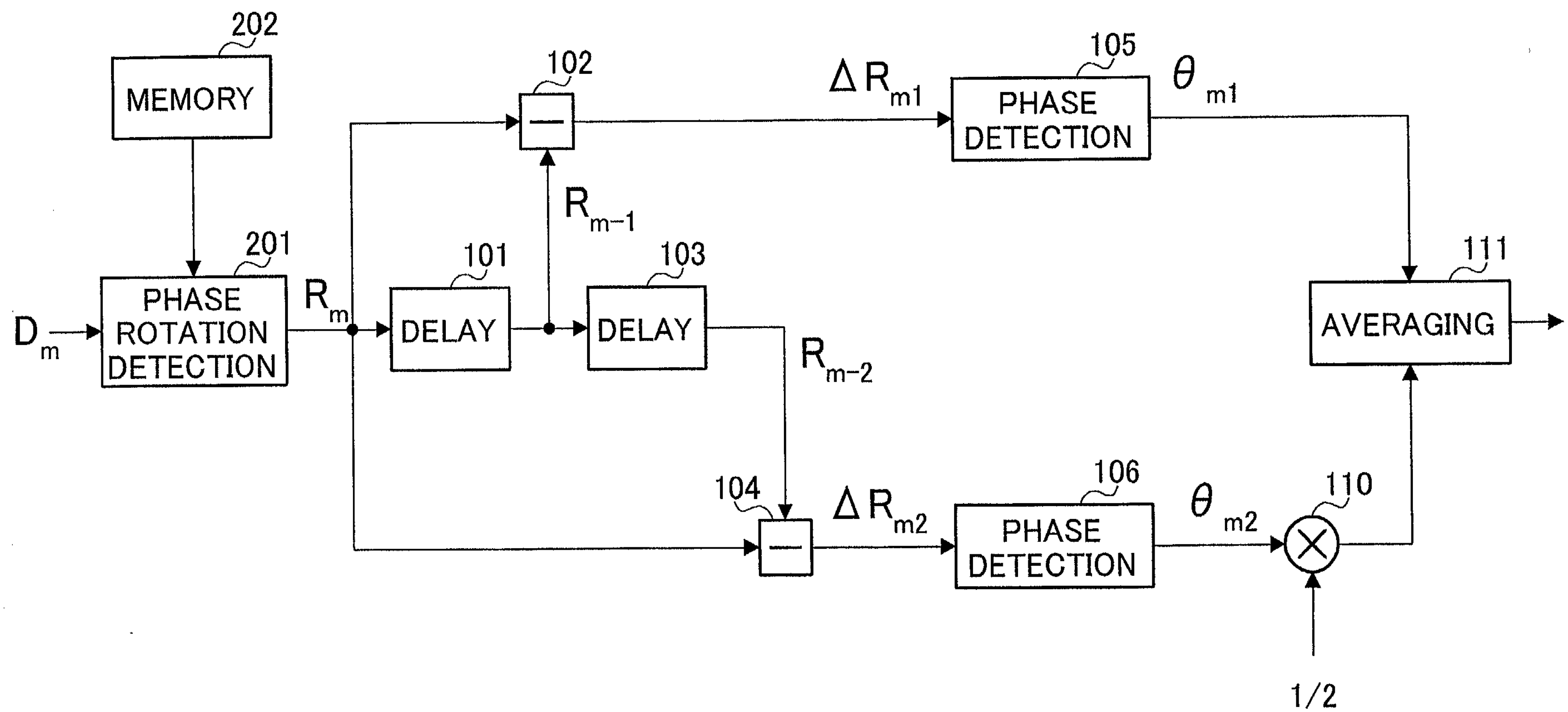


FIG.3A



D_m
101
DELAY
D_{m-1}
103
DELAY
D_{m-2}
102
104
ΔD_{m1}
ΔD_{m2}
105
PHASE DETECTION
106
PHASE DETECTION
θ_{m1}
θ_{m2}
107
MEMORY
ϕ_{m1}
ϕ_{m2}
108
109
110
1/2
111
AVERAGING

FIG.4



MEMORY
202
PHASE ROTATION DETECTION
201
D_m
R_m
DELAY
101
DELAY
103
102
R_{m-1}
R_{m-2}
104
ΔR_{m1}
ΔR_{m2}
PHASE DETECTION
105
PHASE DETECTION
106
θ_{m1}
θ_{m2}
110
1/2
AVERAGING
111

FIG.5

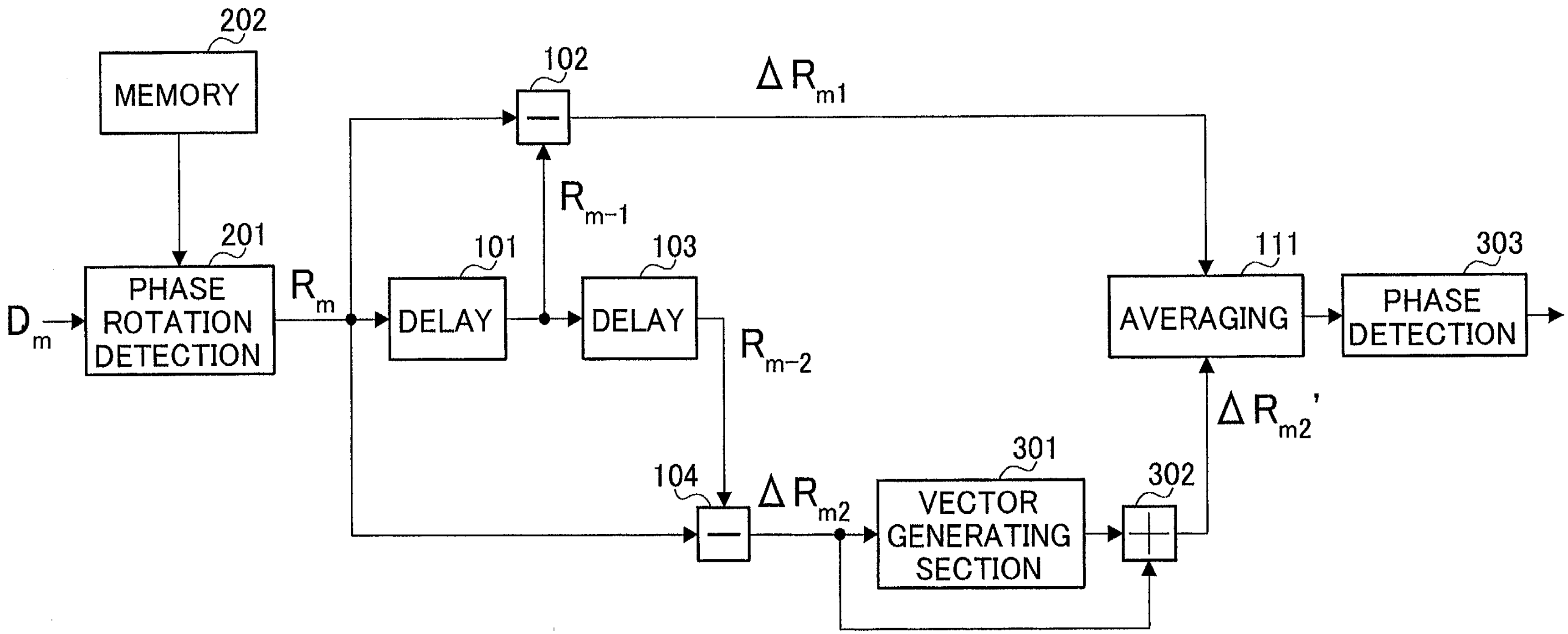

202
MEMORY
201
PHASE ROTATION DETECTION
D_m
R_m
101
DELAY
102
R_{m-1}
103
DELAY
R_{m-2}
104
ΔR_{m1}
ΔR_{m2}
301
VECTOR GENERATING SECTION
302
$\Delta R_{m2}'$
111
AVERAGING
303
PHASE DETECTION

FIG.6

09/787795

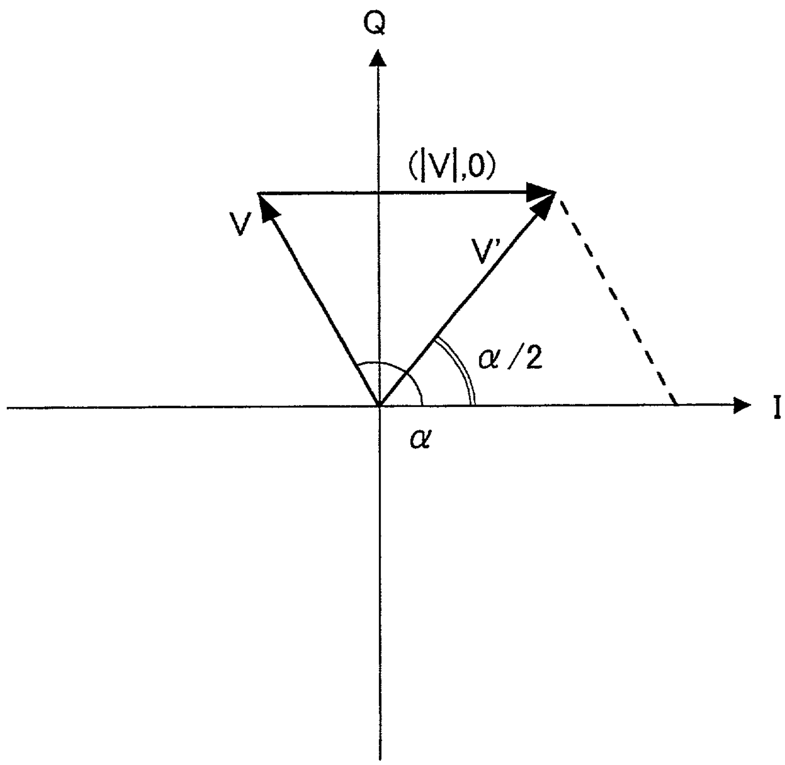


FIG.7

APPLICATION FOR UNITED STATES PATENT
Declaration for Patent Application

As a below named inventor, I hereby declare that:
My residence, post office address and citizenship are as stated below next to my name.
I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on

the invention entitled: FREQUENCY OFFSET QUANTITY DETECTING APPARATUS

the specification of which 2 (file no ____________)

(check at least one) 3 [X] is attached hereto
4 [ ] was filed on ____________ as (5) U.S. Application Serial No. ____________
6 [ ] and was amended ____________ (if applicable)

Use this portion only if you are entering the U.S. National phase based on a PCT International Application designating the U.S.		
	7 [x]	was filed as PCT international application
	8	Number **PCT/JP00/04569**
	9	on **July 10, 2000**
		and was amended under PCT Article(s) 19 and/or 34
	10	on ____________ (if applicable).

I hereby declare that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended, by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me which is material to patentability in accordance with Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application (s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date earlier than that of the application(s) on which priority is claimed.

Prior (Foreign) Application(s) any Priority Claims Under 35 U.S.C. 119 — Priority Claimed

	(Country)	(Number)	(Day/Month/Year Filed)	Yes	No
11a	**JAPAN**	**JP11-213955**	**28/July/1999**	[X]	[ ]
				[ ]	[ ]

[ ] Additional foreign application numbers are listed on a supplemental priority data sheet attached hereto.

Priority Claim(s) from U.S. Provisional Application(s) – I hereby claim the benefit under Title 35, United States Code, §119(e) of any United States provisional application(s) listed below:

11b ____________ ____________ ____________ ____________
Application No. Day/Month/Year Filed Application No. Day/Month/Year Filed

Do not use this portion to identify a PCT application if the parent application is the U.S. National phase of the PCT application	I hereby claim the benefit under Title 35, United States Code, 120 of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code §112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, §1.56 which became available between filing date of the prior application and the national or PCT international filing date of this application. 13 ____________ ____________ ____________ (U.S. Application Number) (U.S. Filing Date) Status (patented, pending, abandoned)

I hereby appoint the following attorneys of the firm of Stevens, Davis, Miller & Mosher, L.L.P. as my attorneys of record with full power of substitution and revocation to prosecute this application and to transact all business in the Patent and Trademark Office:

James E. Ledbetter, Reg. No. 28732; Thomas P. Pavelko, Reg. No. 31689; and Anthony P. Venturino, Reg. No. 31674

ALL CORRESPONDENCE IN CONNECTION WITH THIS APPLICATION SHOULD BE SENT TO STEVENS, DAVIS, MILLER & MOSHER, L.L.P., 1615 L Street, N.W., Suite 850, Washington, D.C. 20036, TELEPHONE (202) 408-5100, FACSIMILE (202) 408-5200.

See page 2 for signature lines

other side for instructions for completing this form

INSTRUCTIONS FOR COMPLETION OF THIS FORM

line 1 Insert the same title as is used on the specification and in the assignment.

line 2 Is optional but is provided so that you can use it to identify more readily an application prior to the time that the Patent Office application serial number is assigned. We suggest that the specification, drawings and declaration always bear a file number since it can help to get the papers together in case they become inadvertently separated. In instances where the specification is filed without a signed declaration form (under 37 CFR §1.53) a file number on a later-received separate form will assist us in associating it with the correct case.

line 3 Check this box if the specification, claims and drawing (if any) are attached to this declaration form, e.g., when filing a new patent application.

lines 4-5 Are only used in an instance where the application is already on file and the declaration from is being separately filed, e.g.,when the application was originally filed without a signed declaration or where the Patent Office has required a new declaration because of a deficiency in the original declaration. In such an instance the Patent Office will require that lines 4 and 5 be completed with the filing date and application serial number already assigned.

line 6 Is used in conjunction with line 5 but only when there have been one or more amendments to the specification or claims. Line 6 is also used when the Examiner requires a new declaration because claims inserted by amendment cover subject matter not originally claimed (37 CFR §1.67).

lines 7-10 Are for PCT (Patent Cooperation Treaty) cases and are used only when you are entering the U.S. National phase (Chapter I or II) based upon a previously filed PCT International application designating the U.S.

line 7 Check this box if this is a PCT National Phase application.

line 8 Insert PCT International application number.

line 9 Insert date of filing of PCT International application.

lines 10 Insert the date of all amendments filed in the PCT International application. Such amendments are optional, so this line at times will not be used.

line 11a Is used in the following instances:

(i) If a single priority is being claimed from a foreign application you need to list only the first-filed application; you do not need to list other countries if all applications were filed within one year of the U.S. filing.

(ii) If multiple priorities are being claimed, from a plurality of applications filed in one or more countries, you must list the first filed application for each aspect of the invention. Example: if aspect A of the invention was disclosed in an application filed 11 months earlier in country X and aspect B was disclosed 9 months earlier in an application filed in country Y, then the applications in both countries X and Y must be identified. Only the first application for each aspect of the invention needs to be identified provided all applications on that aspect were filed within one year prior to the U.S. filing.

(iii) If a non-priority application is being filed you must list all applications in all countries where corresponding foreign applications were filed more than one year prior to the U.S. filing. This is so the Examiner can check to see if any of those applications were published or patented early enough to be prior art against the U.S. application.

(iv) If there are more than two applications to be listed we suggest that you type in on this form only "See attached Schedule A" and then list all of the previous applications on an attached sheet.

line 11b Is used to claim priority under 35 USC §119(e) based on a provisional application filed within one year of the filing of the instant application. More than one provisional application may be identified provided neither was filed more than one year earlier.

line 12 This block is used only in instances where there is a previously filed U.S. non-provisional application which was copending at the time the present application was (or is being) filed. that previous application could be a U.S. non-provisional application or the National Phase of a PCT allocation. In such a case the present application may be entitled to the priority of the previous application's U.S. filing date (and consequently the foreign priority thereof) provided the present application is identified as a continuing application (continuation, divisional or continuation-in-part) of the earlier (parent) application. If the foregoing is applicable, please fill in one line for each such prior application.

line 13 Type the inventor's proper legal name in the order specified, e.g., "John B. JONES" or "J. Bob JONES" if the inventor so prefers. It is not acceptable to use only initials such as "J. B. JONES."

line 14 The inventor's "signature" may be his (or her) usual manner of signing but it is preferable that the inventor simply write his (or her) name in his (or her) own cursive handwriting in the same order as on line 14, e.g., given name, middle initial and Family name.

line 15 Insert the actual date of signature.

line 16 Insert simply the city and state or country, e.g., "Paris, France", of the inventor's residence, not citizenship. No street address or postal code is required on this line.

line 17 Insert the inventor's citizenship. The statement of citizenship (or subject of) is a statutory requirement (35 USC §115). Simply the name of the country of citizenship, e.g., "Japan" is sufficient.

line 18 Insert the inventor's mailing address. The purpose of requiring the post office address is to enable the Patent Office to communicate directly with the inventor if desired, such as in the case of death of the U.S. attorney. It should be the address where the inventor customarily receives his (or her) mail and should include the postal code. If applicable it can be the inventor's business address or address at place of employment.

Applicants are reminded that the U.S. Patent and Trademark Office has very strict requirements as to proper execution of an application. The applicant should make sure that he reviews the declaration, prior to signing to make sure the declaration properly identifies the application and all relevant information; and should review the specification and claims (including drawings, if any) before signing the declaration. Failure to do so will require the filing of a supplemental declaration --- 37 CFR §1.67(c)

Any handwritten changes to the specification, claims or drawings must be in ink personally by all of the inventors prior to signing the declaration and the adjacent left margin must be initialed and dated by all of the inventors, e.g., "JBJ 6-9-91".

Please let us know if there are any questions regarding proper completion of this form. Thank you.

An assignment, a separate document requiring separate signature and dating may be enclosed. Please look for it and sign and date it in the same manner as in lines 15 and 16 above.

STEVENS, DAVIS, MILLER & MOSHER, L.L.P.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful statements may jeopardize the validity of the application or any patent issuing thereon.

PAGE 2 OF U.S.A. DECLARATION FORM

1-00

13a	Typewritten Full Name of Sole or First Inventor	Minako (Given Name)	(Middle Name)	IDE (Family Name)
14a	Inventor's Signature	Minako		Ide
15a	Date of Signature	March (Month)	2 (Day)	2001 (Year)
16a	Residence	Yokohama-shi JPX (City)	Kanagawa (State or Province)	JAPAN (Country)
17a	Citizenship	JAPAN		
18a	Post Office Address (Insert complete mailing address, including country)	2-4-10-102, Kajigaya, Sakae-ku, Yokohama-shi, Kanagawa 247-0009 JAPAN		
13b	Typewritten Full Name of Sole or First Inventor	Given Name	Middle Name	Family Name
14b	Inventor's Signature			
15b	Date of Signature	Month	Day	Year
16b	Residence	City	State or Province	Country
17b	Citizenship			
18b	Post Office Address (Insert complete mailing address, including country)			
13c	Typewritten Full Name of Sole or First Inventor	Given Name	Middle Name	Family Name
14c	Inventor's Signature			
15c	Date of Signature	Month	Day	Year
16c	Residence	City	State or Province	Country
17c	Citizenship			
18c	Post Office Address (Insert complete mailing address, including country)			
13d	Typewritten Full Name of Sole or First Inventor	Given Name	Middle Name	Family Name
14d	Inventor's Signature			
15d	Date of Signature	Month	Day	Year
16d	Residence	City	State or Province	Country
17d	Citizenship			
18d	Post Office Address (Insert complete mailing address, including country)			

*Note to Inventor: Please sign name on line 15 exactly as it appears in line 14 and insert the actual date of signing on line 16. If there are more than four inventors, please add a copy of this page for identification and signatures for the additional inventors.